Biomass distribution patterns of ecotones between forest and swamp in Changbai Mountain

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Abstract: This paper studied the biomass distribution patterns of *Larix olgensis/swamp* ecotones and *Betula platyphlla/swamp* ecotones in Changbai Mountain so as to provide theory foundation for the management of these nature resources, by setting up sample belts, investigating initial data along the environmental gradients change, and establishing regression models. By means of regression models, the biomass of communities, layers, tree species and organs was calculated. In this system, it was found that the community biomass increased gradually along the environmental gradients change from swamp to forest in Changbai Mountain. Furthermore, the ecotoneal biomass distributed mainly over tree layer. The tree biomass distributed mainly in two or three dominate tree species.

Key words: Biomass distribution patterns; Ecotones; Changbai Mountain
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Introduction

Understanding the distribution patterns of biomass along environmental gradients change from swamps through ecotones to forests is vital not only for revealing the law of ecotoneal community structure, function and succession, but also for conserving and managing ecotoneal communities. Research results showed that conditions stressful in other environments might increase primary production in plants adapted to wetland ecotones. For example, Sharma and Gopal (1977) studied biomass structure in the cattail along a gradient from open water through wetland to upland. In the dry upland stand, flooded occasionally for a short period, aboveground biomass was small, maximum biomass was obtained in the middle stand which was flooded frequently, and the permanently flooded stand had intermediate values. It seems important for future studies to focus on analyses of productivity at wetland-upland or wetland-open water ecotones. Due to difference in climate, vegetation as well as soil between the former and Changbai Mountain, the distribution patterns of the ecotones biomass may be different. However, no one did the research so far.

This paper aimed at revealing the biomass distribution patterns of *L. olgensis*/swamp ecotones and *B. platyphlla*/swamp ecotones in Changbai Mountain to provide theory foundation for conserving and managing ecotoneal community nature resources. By means of regressive equations, we calculated the biomasses of communities, layers, tree species and organs in these kinds of ecotones. The results showed that the community biomass showed a clear gradient distribution along two kinds of ecotonal environmental gradients in Changbai Mountain. The ecotonal biomass distributed mainly over tree layer. The tree biomass distributed mainly in two or three dominative tree species.

Methods and sites

Description of site

The sites located in Changbai Mountain at altitudes of 450-800 m above see level. The dominant species of swamp community were *Cares schmidtii* and *Sausurea serrata*. Along an environmental gradient from swamp to forest, habitats changed gradually with topography becoming higher, underground water stage lowing, period flooded becoming short, amount of flooded reducing and peat layer thinning. Forest tree species invaded swamps gradually,

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formed forest and swamp ecotones. Due to difference of habitats and forest types, there are two typical forest and swamp ecotones in Changbai Mountain. One is the *Larix olgensis/swamp* ecotone. Although the ecotoneal breadth is only about 90 m, Community dominant tree species are in turns by *Alnus Japonica* (15 years old), *Larix olgensis* (40 years old) and *Betula platyphylla* (35 years old). The thickness of peat layer changed from 8 cm to 45 cm. The stage of underground water was from 25 cm to 76 cm. The rate of patch was from 50% to 85%. Another is the *Betula platyphylla/*swamp ecotone. The community dominant tree species were *Betula platyphylla, Salix rosmarinifolia* and *Populus davidiana*. Its breadth is about 60 m. Thickness of peat layer changed from 25 to 100 cm, stage of underground water from 12 to 31 cm, rate of patch from 42% to 70% and stand age changed from 17 years old to 25 years old.

Investigating methods of community biomass

The sample strips were set up along these kinds of ecotoneal environmental gradients from typical swamp through wetland-upland ecotone to typical forest. Sample strip was 30 m wide, 60 m or 90 m long. The sample strips were divided into 72 or 108 little sample plots of 5 m × 5 m. Then we investigated the community component, growth of trees in diameter and height on each sample plot and divided the diameter classes by 2 cm. In each class of diameter, we selected 3-5 sample trees to survey their biomass in the same community, then, estimating the constructions of biomass of community. The biomass of herbage and shrub was obtained from 36 plots of 5 m × 5 m (Table 2-4, Fig. 1-3).

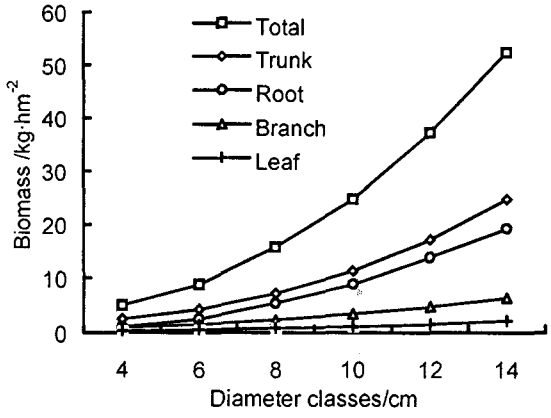

Fig. 1. Biomass distribution of different diameter classes of *Alnus japonica*

Analyzing methods of tree biomass

Dimensional analysis is a commonly used method to calculate biomass of tree organs. There were several kinds of equations being used, such as logarithm, power, polynomial, exponential, linear and so on (Jiang *et al.* 1990; Liu *et al.* 1994; Mu *et al.* 1995; Zheng *et al.* 1998). However, in the wetland-upland ecotones condition, we found that the cubic equations were fitted by SYSTAT software (Table 1).

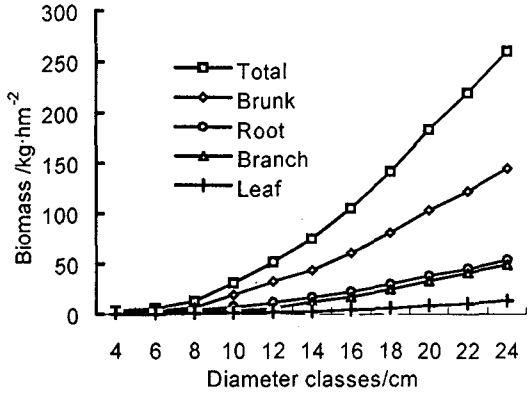

Fig. 2. Biomass distribution of different diameter classes of *Betula platyphlla*

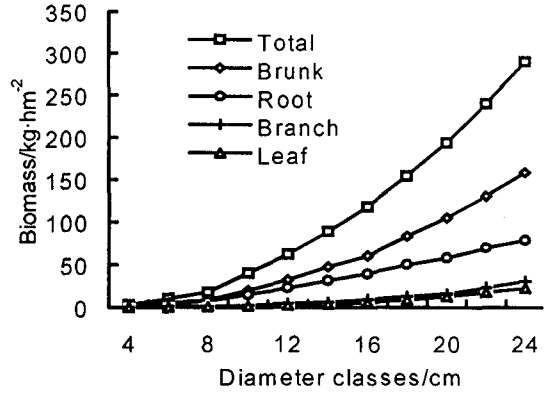

Fig. 3. Biomass distribution of different diameter classes of *Larix olgensis*

Results and analyses

Distribution of community biomass

Table 2 showed the analysis result of community biomass of two kinds of ecotones between forests and swamps. We found that the biomass of communities all increased gradually along environmental gradients change from swamps to forests in Changbai Mountain. In the ecotones between *L.olgensis* and swamp, community biomass of nearly typical swamps (0-30 m) was 22.98 t·hm^{-2}, the biomass of far from swamps (30-60 m) increased to 83.11 t·hm^{-2}, which was 3.6 times more than that of the former.

The biomass of nearly typical forest (60-90 m) reached 132.48 t·hm^{-2} which increasing to 5.2 times. In the ecotones between *B. platyphlla* and swamp, community biomass of nearly typical swamps (0-30 m) and nearly typical forest (30-60 m) was 18.86 t·hm^{-2}, and 57.15 t·hm^{-2}, which increased by 2.6 times. Community biomass showed a clear gradient distribution along these kinds of ecotonal environmental gradients.

Table 1. Regression models of distribution of tree biomass of diameter classes between forests and swamps ($Y=b_0+b_1D+b_2D_2+b_3D_3$)

No	Species	Biomass/t·hm^{-2}	b_0	b_1	b_2	b_3	Rsq.	Sigf	S.n	Domain/cm	Model tape
1		Total	3.904	-0.839	0.259	0.003	0.999	0.000	6	[4,16]	Cubic
2		Trunk	1.172	0.082	0.042	0.005	0.999	0.000	6	[4,16]	Cubic
3	*A. jaoponica*	Root	2.438	-1.126	0.211	-0.003	0.999	0.000	6	[4,16]	Cubic
4		Branch	0.577	0.0013	0.0244	0.0004	0.999	0.000	6	[4,16]	Cubic
5		Leaf	-0.282	0.204	-0.018	0.0011	0.996	0.000	6	[4,16]	Cubic
6		Total	25.21	-9.877	1.175	-0.015	0.998	0.000	11	[4,24]	Cubic
7		Trunk	11.130	-4.948	0.634	-0.009	0.999	0.000	11	[4,24]	Cubic
8	*B. platyphla*	Root	4.957	-1.760	0.226	-0.0028	0.996	0.000	11	[4,24]	Cubic
9		Branch	8.142	-2.821	0.261	-0.003	0.998	0.000	11	[4,24]	Cubic
10		Leaf	0.976	-0.345	0.034	7.3E-05	0.999	0.000	11	[4,24]	Cubic
11		Total	3.149	-2.687	0.641	-0.0014	0.999	0.000	11	[4,24]	Cubic
12		Trunk	2.639	-1.743	0.347	-0.0002	0.999	0.000	11	[4,24]	Cubic
13	*L. olagensis*	Root	1.708	-1.297	0.317	-0.0054	0.999	0.000	11	[4,24]	Cubic
14		Branch	-2.439	0.749	-0.056	0.0034	0.998	0.000	11	[4,24]	Cubic
15		Leaf	-0.093	0.113	-0.022	0.0024	0.999	0.000	11	[4,24]	Cubic

Table 2. Biomass distribution of ecotones between forest and swamp t·hm^{-2}

Ecotone	Habitat/m	Tree		Brush		Herb		Community	
		Biomass	%	Biomass	%	Biomass	%	Biomass	%
B.platyphlla /Swamp	0-30	10.92	68.85	1.16	7.31	3.78	23.83	15.86	21.72
	30-60	52.24	91.41	1.52	2.66	3.39	5.93	57.15	78.28
Total		63.16	86.51	2.68	3.67	7.17	9.82	73.01	100.00
L.olgensis /Swamp	0-30	20.10	87.47	1.28	5.57	1.60	6.96	22.98	9.63
	30-60	79.21	95.31	2.73	3.28	1.17	1.41	83.11	34.84
	60-90	126.90	95.79	4.65	3.51	0.93	0.70	132.48	55.53
Total		226.21	94.82	8.66	3.63	3.70	1.55	238.57	100.00

Biomass distribution among community layers

Table 2 also showed that the ecotonal community included three layers such as tree, shrub and herbage. Tree biomass was dominant in communities in different habitats. Tree biomass increased gradually, nevertheless, brush and herbage biomass decreased along the environmental gradients change from swamp to forest. In the *L. olagensis*/swamp ecotones, tree biomass took up 94.82 %, shrub 3.63% and herbage 1.55 % of community biomass. In the *B. platyphla*/swamp ecotones, tree biomass was 86.51%, shrub 3.67% and herbage 9.82% of all community biomass. *L. olagensis*/swamp and *B. platyphla*/swamp ecotones had dominant tree layers. The difference between them was that *L. olagensis* herbage biomass was higher than its shrub's, but another was that shrub biomass was higher than herb's. At the same time, tree biomass increased from 87.47% to 95.79% or from 68.85% to 91.41% of all biomass. Shrub and herb biomasses decreased gradually along the environmental gradients change from swamp to forest.

Tree biomass distribution

From Table 3, we founded that the tree biomass distributed mainly in two or three tree species of ecotones between forest and swamp. In the *B. platyphla*/swamp ecotone, there were three dominant species of tree, such as *B. platyphla* (42.1%), *S. rosmarinifolia* (23.8 %) and *P. davidiana* (20.8 %); their percentage reached 86.7 %. Nearly swamp

habitat, there were for only three tree species, yet, nearly forest habitat for seven. In the *L. olagensis*/swamp ecotones, the dominant tree species were *L. olagensis* (50.0%), *B. platyphla* (27.1%), and *A. japonica* (20.7%), their percentage of total biomass reached 97.8%. Nearly swamp habitat, there were only two tree species, nearly forest habitat for five.

Organ biomass distribution

In order to compare differences of organ biomass distribution in different communities, we calculated the organ biomass in all diameter classes by using regression equation (Table 1). Then total organ biomass was obtained on basis of community diameter classes' distribution (Table 4). Table 4 indicated that different organ had different biomass rate to that of total tree. The order is trunk > root > branch > leaf. Their rate is that 5.5:3:1:0.5 in the *L. olagensis*/swamp ecotones, and 6:2.5:1:0.5 in the *B. platyphla*/swamp ecotones approximately. Along the environmental gradients change from swamp to forest, the trunk biomass increased gradually, the root biomass decreased on the contrary. The branch and leaf biomass had little difference among all types

Table 3. Distribution of tree biomass of forest and swamp ecotones

Ecotones	*B. platyphla*/swamp ecotones				*L. olagensis*/swamp ecotones				
	0-60 m		0-30 m	30-60 m	0-90 m		0-30 m	30-60 m	60-90 m
	Biomass/ t·hm^{-2}	%	%	%	Biomass/ t·hm^{-2}	%	%	%	%
B. platyphlla	26.2	42.1	11.3	30.9	61.2	27.1		4.0	23.0
S. rosmarini.	15.0	23.8	5.7	18.1					
P. davidiana	13.1	20.8	0.3	20.4	4.1	1.8			1.8
M. amurensis	4.9	7.8		7.8					
R. davurica	1.6	2.5		2.5					
B. costata	1.1	1.7		1.7					
F. mandshurica	0.8	1.3		1.3	0.9	0.4			0.4
A. japonica					46.8	20.7	4.8	10.3	5.6
L. olgensis					113.2	50.0	4.1	20.6	25.3
Total	63.1	100.0	17.3	82.7	226.2	100.0	8.9	34.9	56.1

Table 4. Distribution of organs biomass of ecotones between forest and swamp t·hm^{-2}

Ecotones	Habitat/m	Trunk		Branch		Leaf		Root	
		Biomass	%	Biomass	%	Biomass	%	Biomass	%
B. platyphlla /Swamp	0-30	6.08	55.7	1.09	10.0	0.37	3.4	3.38	31.0
	30-60	31.69	60.7	5.76	11.0	1.96	2.3	12.82	24.5
	0-60	37.77	59.8	6.85	10.8	2.33	3.7	16.20	25.7
L. olgensis /Swamp	0-30	9.83	48.9	2.58	12.8	0.99	4.9	6.70	33.4
	30-60	41.10	51.9	8.67	11.0	4.35	5.5	25.05	31.6
	60-90	69.86	55.1	14.69	11.6	6.01	4.7	36.26	28.6
	0-90	120.79	53.4	25.94	11.5	11.35	5.0	68.01	30.1

Conclusions and discussion

The community biomass showed a clear gradient distribution along two kinds of ecotonal environmental gradients in Changbai Mountain. The biomass of nearly typical swamps (0-30 m) of ecotones between *L.olgensis* and swamp was 22.98 t·hm^{-2}, far from swamps (30-60 m) for 83.11 t·hm^{-2}, nearly typical forest (60-90 m) for 132.48 t·hm^{-2}. In *B. platyphlla*/swamp ecotones, biomass of nearly typical swamps (0-30 m) and nearly typical forest (30-60 m), was 18.86 t·hm^{-2} and 57.15 t·hm^{-2}. This was mainly because that the ecotone had an environmental gradient from swamp to forest, on which patch area became bigger. The habitats changed from flooded frequently to occasionally for a short period, which not only affected the stand age structure, but also did tree growth. This kind of biomass distribution pattern was different (Sharma 1977) due to the difference of climate and vegetation.

Furthermore, the ecotonal biomass distributed mainly over tree layer. The tree biomass distributed mainly in two or three dominate species of tree. In the meantime, the tree biomass and species number increased gradually (Mu *et al.* 1998), nevertheless, brush and herbage biomass decreased along the

environmental gradients change from swamp to forest. The order of biomass rate of organ is trunk > root > branch > leaf. Their rate approximately was 5.5:3:1: 0.5 in the *L.olagensis*/swamp ecotones, and 6:2.5:1:0.5 in the *B. platyphla*/swamp ecotones. Along the environmental gradients change from swamp to forest, the trunk biomass increased gradually and the root biomass decreased on the contrary; the branch and leaf biomass had little difference among all types.

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